

# Generation 3 Mobile Displays

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San Jose January 23-24, 2001

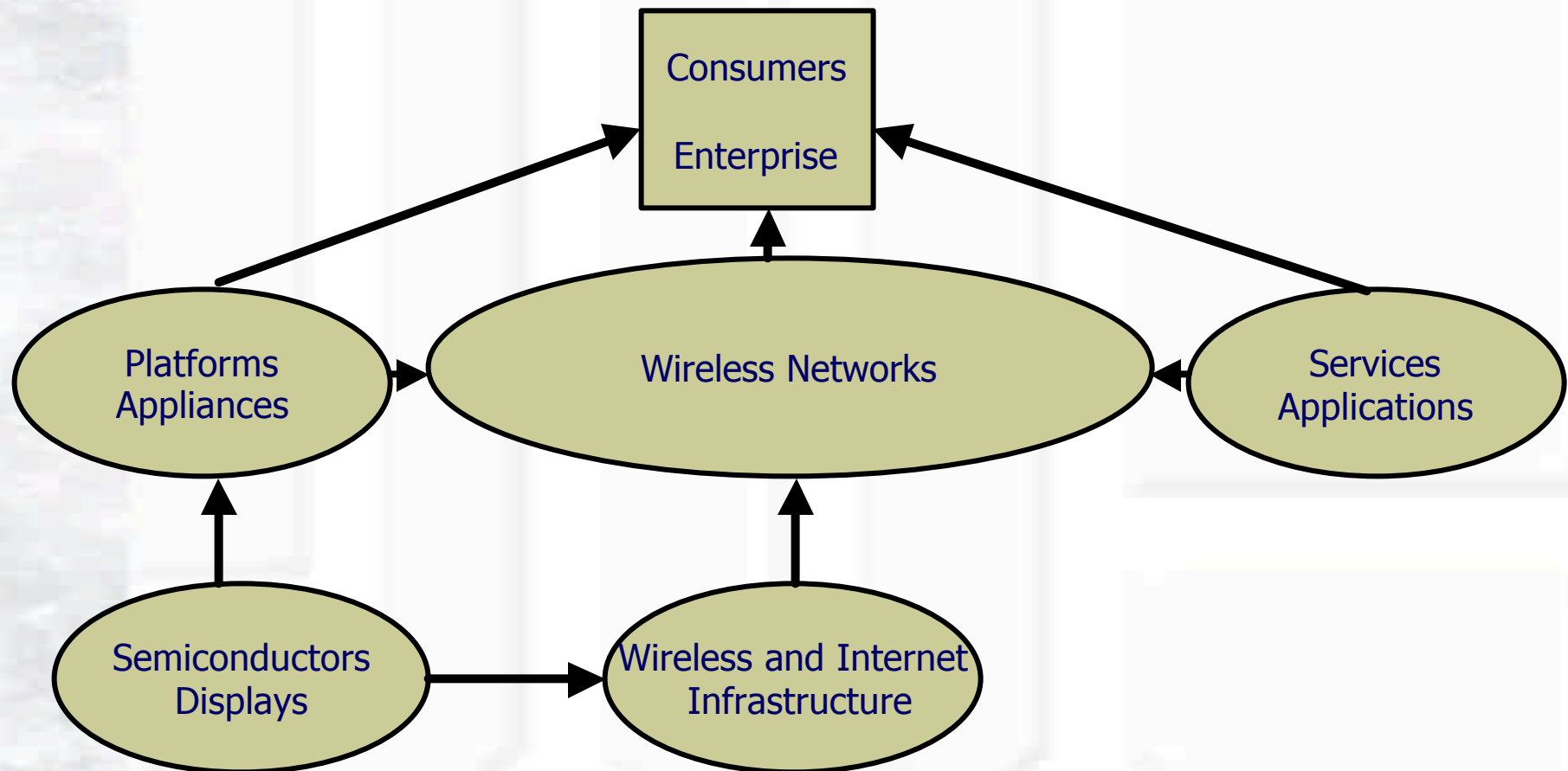


Taipei February 14-15, 2001

# Outline of Presentation

- Overview of Market Trends and Players
- Services and Applications
- Platforms and Appliances: Display Requirements
- Passive Matrix LCDs: Can the revival be sustained?
- Active Matrix LCDs: Will poly silicon displace amorphous?
- OLEDs: Can a new technology go toe to toe with LCDs?
- Microdisplays: A mobile solution with the capability of a monitor
- Forecasting the winners

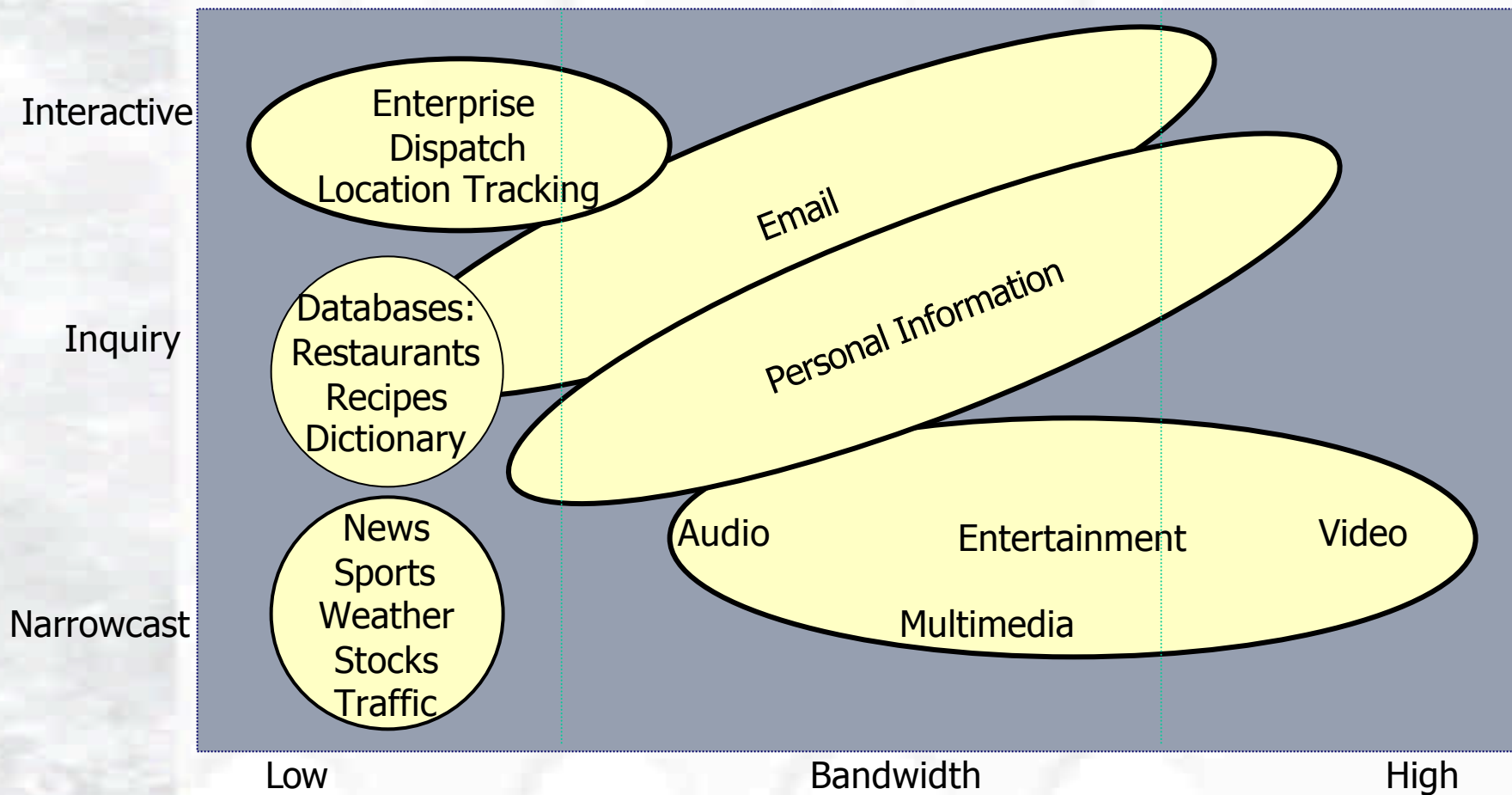
# Wireless Networks: at the Market Core



# Wireless Network Trends

- Wireless Network Companies: Neck of the Bottle
  - G2 Voice services generate revenues and prof
  - G3 services require huge new investment in infrastructure
  - Consumers prefer buying bundled services and hardware from Networks
- I-mode vs. GSM/WAP
  - NTT Docomo I-mode services prove extremely popular in Japan
  - GSM/WAP services in Europe have not been as successful
  - Consumer cultural preferences or Internet access demographics?
- Lessons To Date
  - G2.5 packet switching and always on enable popular services
  - Pricing of services is extremely critical to spur adoption
  - Many low bandwidth services are widely embraced
  - Color display capability is more critical than higher pixel counts

# Applications and Services



# G3 Handheld Platforms



## Voice Cellphone

Small, light, convenient  
I-Mode functionality

## Wireless Communicator

G3 mainstream product  
Micro-browser and PIM  
Customizable set of  
applications

## Wireless PDA

Data centric appliance  
3rd party OS and applications



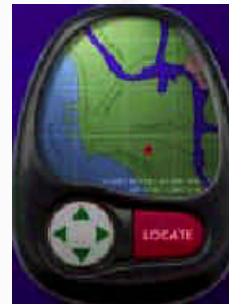
# G3 Appliances



The "Dude's" Cellphone



Wallet Cellphone



Pocket Navigator



Keychain Cellphone



Compact Cellphone

Source: Qualcomm

# 2002 Display Requirements

Mode	Voice Phone	Wireless Communicat	Wireless PDA	Headset
Diagonal (in.)	1.6	2.8	3.8	10 inch
Pixels H	96	240	320	virtual 640
Pixels V	90	160	240	480
Color/Mono	Mono	2 color	3 colors	3 colors
Gray Levels	Na	4	4	4
Colors	Na	256	4096	4096
Video	Na	Video	Yes	Yes
Module Power	<3 mW	<10 mW	<100 mW	<100 mW
Module Price	\$5.00	\$20.00	\$30.00	\$75.00
Like Technology	STN LCD	Active Address STN LCD	Backlit AMLCD	Reflective LCOS
System Price	\$60	\$150	\$250	\$300



# G3 Display Technologies

- Passive Matrix Liquid Crystal Displays (PMLCD)
  - Incumbent technology, low power and cheap, but....
- Active Matrix Liquid Crystal Displays (AMLCD)
  - Can the laptop display be down sized to compete?
- Organic Light Emitting Diodes (OLED)
  - A bright and pretty face on the horizon
- Microdisplay Personal Displays
  - A desktop monitor on a chip

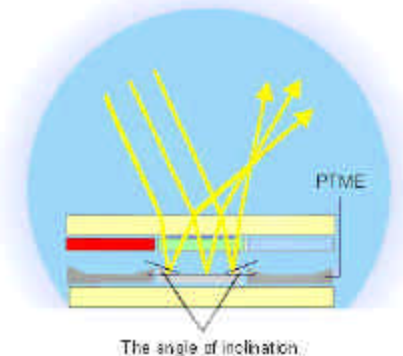
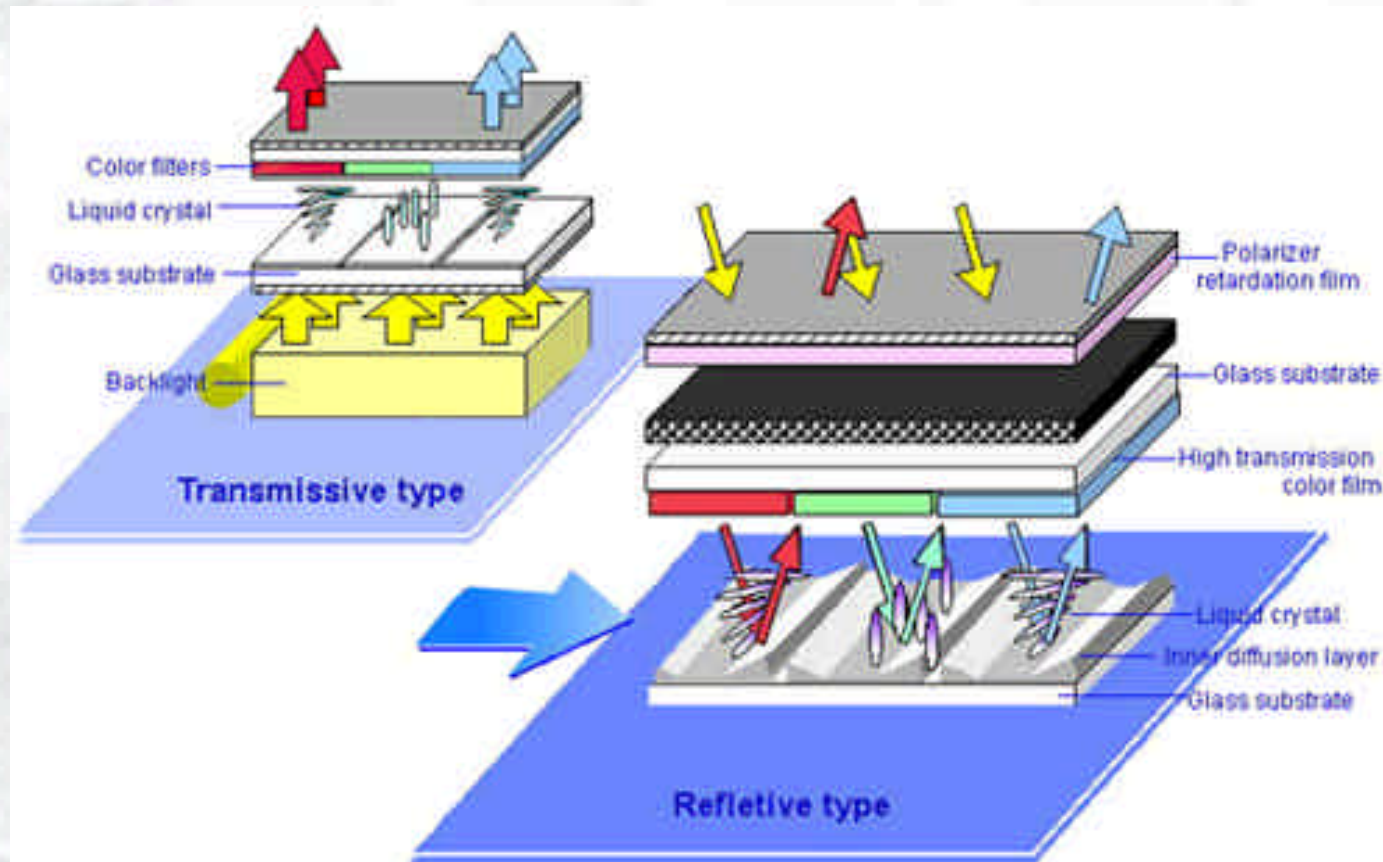
# Passive Matrix LCDs

- Incumbent display technology for cellphones and PDAs
  - Offers lowest power and price
  - Legible text and graphics, but a face that only a mother could love
- Display Module is custom configured for each cellphone model
  - Module includes display, controller and driver IC, and night light
- Typical “transflective” or “night-lit” mode
  - Display is reflective in outdoor or well lighted ambients
  - Nightlight (LED or EL backlights) can only be seen in the dark
- PMLCDs, or STN displays lost the laptop war in late 90s
  - Active matrix LCDs dominate laptops, monitors, and TVs
  - PMLCDs have low contrast and poor color saturation
  - Conventional STNs are too slow to display video images

# PMLCD Market Trends

- Cellphone demand has revitalized the PMLCD industry
  - STN laptop factories have been refitted to make cellphone displays
  - Nearly forgotten technology improvements have resurfaced
- Improvements are being rolled out on several fronts
  - Reflective color implemented in I-Mode cellphones
  - Active addressing enables video rate performance
  - Refresh function is integrated into controller for further power saving
  - Thin and robust plastic substrates implemented by Sharp and Matsushita
  - More efficient front lighting will be introduced in next generation
- Massive expansion of capacity to meet market demand
  - Driver and controller chips are currently in short supply
  - Module assembly and test capacity is stretched

# Color Reflective Technology



# PMLCD Players

- Monochrome  
**(99 Market Share)**
  - Epson (22%)
  - Samsung (16%)
  - Philips (14%)
  - Optrex (10%)
  - Sharp
  - Three Five
- Color
  - Epson (40%)
  - Sharp (40%)
  - Casio (14%)
  - Optrex

## Monochrome

Extremely price competitive market

Dominance of leaders is eroding

Smaller companies gaining share

Driver and controller IC shortages

## Color

Leaders have significant IP for both LC and IC technology

Second tier manufacturers struggle to keep pace

# Active Matrix LCDs

- Two camps of AMLCD suppliers
  - Big screens for laptops, monitors and TVs
  - Small full color video displays for cameras and handheld TVs
- Vast majority of displays are backlit full color video capable
  - High power backlights are required to enable daylight viewing
  - Even small (2-3 inch) AMLCDs burn 500 mW
- Several backplane technologies compete in small displays
  - Amorphous silicon has been extended to small sizes
  - Low temperature poly-silicon (LTPS) enables integration of drivers
  - Epson sustains thin film diode backplane technology
- Few of the big AMLCD players compete in small sized displays
  - Major players are preoccupied with selling out their capacity



# Small AMLCD Trends

- Camcorder monitors, Win CE handhelds dominate usage
  - Current 2.5 inch monitors cost \$40.00 and consume ~ 500 mW
  - Handheld 5 inch QVTA displays cost \$ 80.00; consume ~ 800 mW
- Low power reflective color models have been introduced
  - 3.7" QVGA at 20 mW with front light (Sony)
  - 1.7" cellphone at 5 mW
- Low temperature poly-silicon (LTPS) offers strategic advantage, but a-Si suppliers continue to be competitive
  - Lower bill of material costs for p-Si offset by lower yields
  - LTPS cost should be significantly lower by 2003

# Small AMLCD Players

- Amorphous Silicon  
**(99 Market Share)**

- Sharp (50%)
- Casio (37%)
- Epson (13%)

- LT poly-Silicon
  - Sanyo (83%)
  - Sony (17%)
  - Matsushita
  - Toshiba

## Amorphous Silicon

Sharp has captive camcorder market

Casio is leading merchant supplier

Taiwanese have minor market share

## LT poly-Silicon

Sanyo has focused on small displays

Sony aggressively promoting reflective front lit low power units

Pricing? How low will they go?

# OLED Displays

- OLEDs, the Great Bright Hope for portables
  - Potential for CRT-like imaging: bright full color video
  - Ultra thin profile (~ 1 mm) emissive flat panel
  - Low voltage and low power
- Small multi-color character displays are already in production
  - Implemented in Pioneer audio system and Motorola cellphone
  - >10 manufacturers are scaling up to production
- Combines proven flat panel fabrication processes and equipment with new families of organic materials
  - Already several families of OLED materials being implemented
  - Major opportunities for improvements and breakthroughs

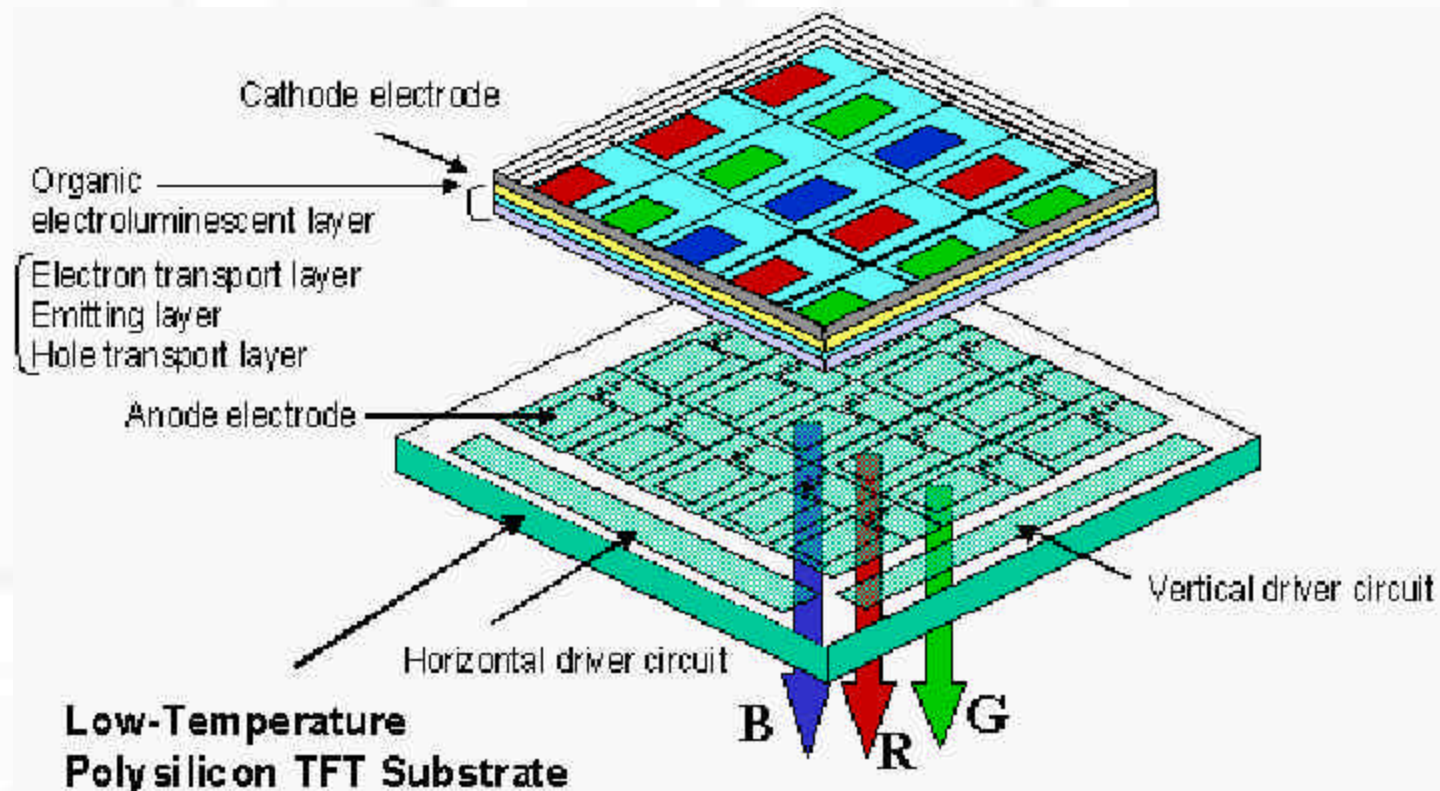


# OLED Trends

- Evolving state of brightness, power, and lifetime
  - Lifetime of current OLED materials  $\ll$  10 K hours at high brightness
  - Kodak, Dow, and others are busy introducing improved materials
- Limitations of passive matrix OLEDs
  - Passive drive is limited to small cellphone displays (~ 100 lines)
  - Active matrix drive needed for larger full color video displays
  - Higher current capability of LTPS is best fit for OLEDs
- Bright and beautiful, but.....
  - Fab investment about the same as LCDs
  - Potential for lower materials costs, but yields probably lower
  - OLEDs may match LCD cost within several years
  - Sunlight readability will always be a challenge

# OLED Technology Trends

Typical Construction of Active Matrix OLED



# OLED Players

## Display Makers

Pioneer  
Sanyo  
TDK  
Infineon  
Philips  
Emagin  
Ritek  
Epson  
Samsung NEC

## OLED Materials

Kodak  
Dow  
Cambridge Display  
Dupont  
Covian

- First gen passive matrix displays
  - Pioneer is market leader
  - >10 Fabs under construction
  - Cellphones are principal market target
- Next gen active matrix displays
  - Multiple demonstrations of prototypes
  - Volume production promised in 2003
  - Sanyo and Epson leverage LTPS capability
- Prolific development of materials
  - Multiple families of small and large molecules



# Organic Light-Emitting Diodes



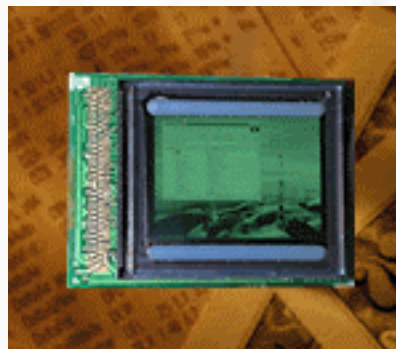
Cambridge Displays



Kodak/Sanyo SID 2000



Universal Displays



eMagin Corp

# Microdisplay Personal Displays

- Near eye alternative: handheld desktop information content
  - Embedded viewers and headsets with SVGA full color video
  - Compact low power, low cost, alternative
- Developers currently focused on camcorder and DSC market
  - Sony dominates camcorder space with HTPS LCD viewfinders
  - Liquid crystal on Silicon (LCOS) suppliers are challenging Sony and developing DSC applications
  - QVGA viewfinders offer full color video for <\$20.00 and <50 mW
- Both embedded and headset displays proposed for wireless
  - Peripheral SVGA headset display for cellphone, PDA, laptop, DVD
  - Embedded display in palm or wrist appliance

# Microdisplay Trends

- Headsets fail to attract broad based market demand
  - Quest for the universal headset peripheral remains unfulfilled
  - Marginal ergonomics, nerd factor, comfort, and price all contribute
  - Vertical markets are also slow in developing
  - Portable DVD and game applications put off by high pricing
- Never before have so many developers offered so many attractive headset solutions
  - Olympus, Sony, Shimadzu, Dayeang, and others
  - Xybernaut, IBM, others evolve wearable computers
- Internet handheld appliance with embedded viewer
  - Inviso continues to define the path

# Personal Display Products



# Personal Display Players

## Headset Makers

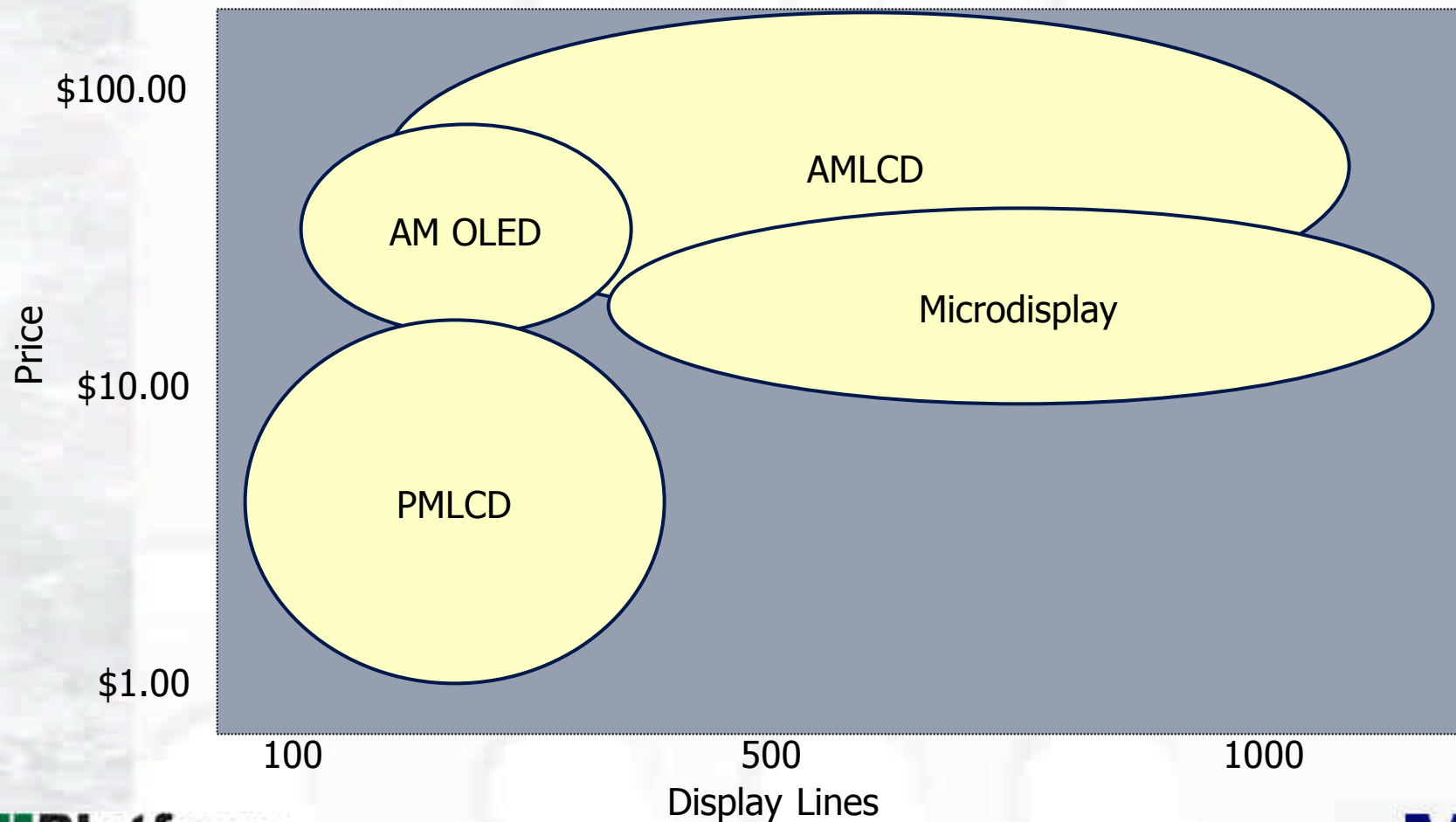
Sony  
Olympus  
Shimadzu  
Micro Optical  
Virtual Vision  
Inviso

## Microdisplay Makers

Colorado Microdisplay  
Inviso  
Kopin  
Displaytech  
Microdisplay Corp  
eMagin

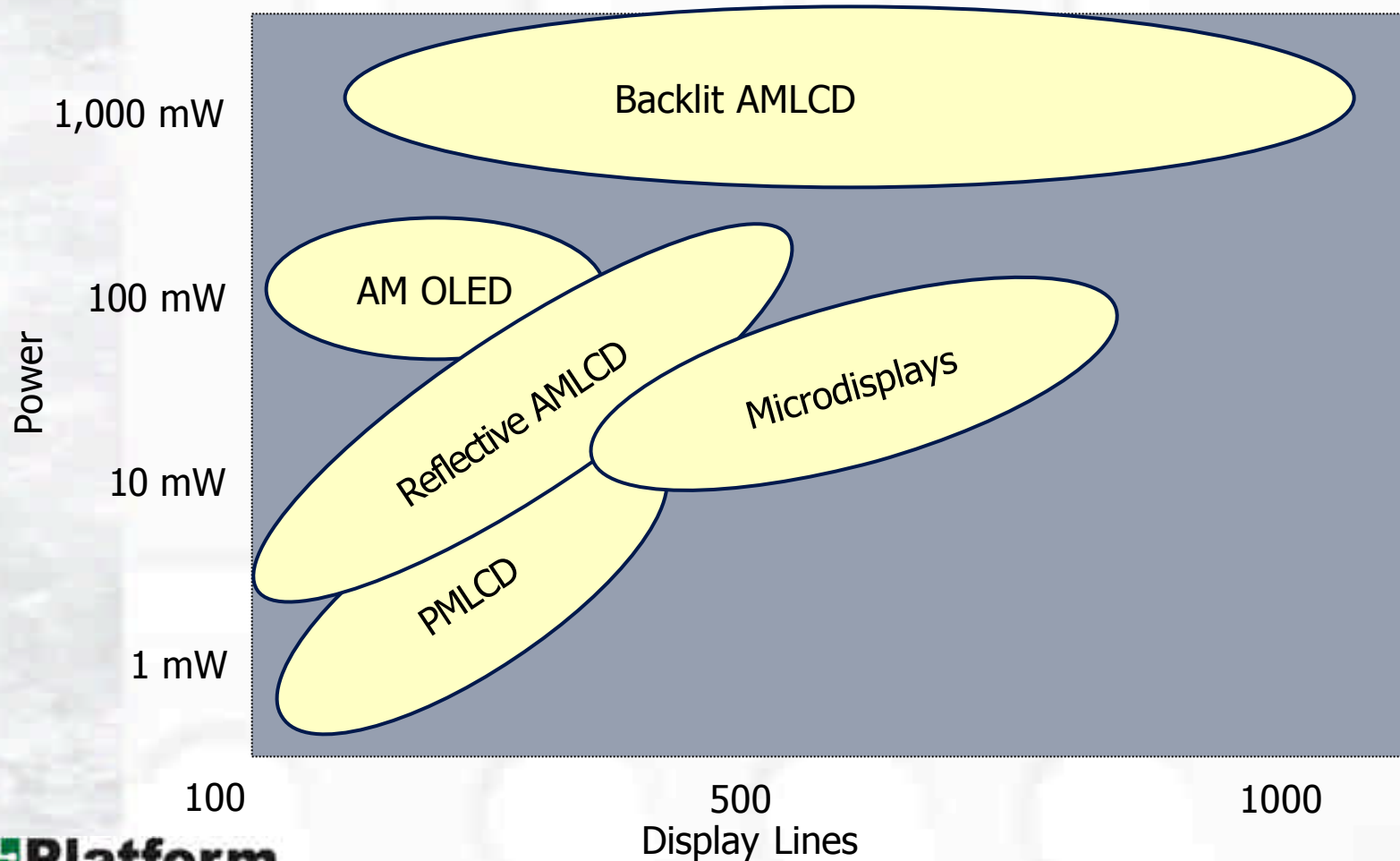
- Headset makers sustain improvements
  - Constant improvement; no breakthroughs
  - Better imaging, bigger sweet spots
  - Pricing > \$500 limits consumer interest
- Microdisplays are much improved
  - Color and video improvement
  - Magnifying optics still somewhat limited
  - Major power reductions underway
  - Pricing for SVGA < \$50 per eye

# Display Price Comparison





# Display Power Comparison



# Platform Display Technology Matrix

		Voice Phone	Wireless Communicator	Wireless PDA	Headset Peripheral
	Technology				
PMLCD					
	Transflective Backlit				
	Monochrome characters	●			
	Monochrome graphic	●	●	●	
	Color graphic	●	●	●	
AMLCD					
	Reflective Color	●	●	●	
	Backlit Color				
OLED					
	PM	●			
	AM		●	●	●
Microdisplays					
	Embedded				●
	Headset Peripheral				

# G3 Competitive Outlook

- Voice Phones
  - Display decision dominated by price and power
  - Cheap nightlit PMLCDs will continue to dominate value segments
  - Color reflective PMLCDs and AMLCDs will vie with OLEDs for style driven high priced segments
- Wireless Communicators and PDAs
  - Color reflective passive and active matrix LCDs will compete for market leadership in value segments
  - OLEDs and backlit AMLCDs will compete for high performance segments
- Epson, Sony, Sanyo, Samsung, and Philips will be the major players